

Classification of the Cyprinid Genus *Sarcocheilichthys* from Japan, with Description of a New Species

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Abstract Populations of the cyprinid genus *Sarcocheilichthys* from various localities in Japan and Korea were morphologically compared. On the basis of principal component analysis, Japanese *Sarcocheilichthys* are classified into two species and two subspecies, i.e. *S. variegatus variegatus*, *S. variegatus microoculus*, and *S. biwaensis*, sp. nov. *S. variegatus variegatus* occurs solely in rivers, and has a short head, a greyish body color and a broad, black cross bar on the dorsal fin. *S. variegatus microoculus* inhabits Lake Biwa and adjacent rivers, and has a comparatively long head, a greyish body color, and a broad, black cross bar on the dorsal fin. *S. biwaensis* inhabits basalt rocky or pebbly shores of Lake Biwa, and has a long head, a brownish yellow body color and a rudimentary cross bar on the dorsal fin.

The cyprinid genus *Sarcocheilichthys* is distributed in eastern Asia northeast from the Amur basin and Japan southwest to northern Vietnam and Hainan. Some ten species have been described in the genus. Bănărescu and Nalbant (1967) reviewed the genus and recognized the following five species: *S. nigripinnis* (Günther), *S. variegatus* (Temminck et Schlegel), *S. microoculus* Mori, *S. parvus* Nichols, and *S. sinensis* Bleeker.

Japanese forms of *Sarcocheilichthys* are quite variable in morphological characters, particularly in coloration and head length in relation to standard length. Fishermen on Lake Biwa have empirically recognized two groups in terms of coloration, i.e. greyish and brownish groups, and divided the former into three groups according to relative head length: long-headed individuals (tsuranaga in Japanese), short-headed individuals (tōmaru) and medium-size-headed individuals (higai). Bureau of Fisheries (Japan) (1938) further bisected the greyish medium-size-headed individuals in Lake Biwa into intensively speckled littoral individuals and less intensively speckled limnetic individuals. Incorporating all these observations, Nakamura (1969) recognized the following forms:

Coloration greyish (ordinary color in Nakamura, 1969)

Short-headed form

Medium-size-headed form

Littoral form

Limnetic form
Long-headed form
Coloration brownish, head medium-sized
Yellow-brown form
Pale violet-brown form

Taxonomically, recent Japanese workers have generally regarded the above forms as representing variants, or possibly subspecies, within a single species, *S. variegatus* (e.g., Nakamura, 1963, 1969; Niwa, 1967; Miyadi et al., 1976), though Mori (1927) considered the greyish long-headed form to be a distinct species, *S. microoculus*. Bănărescu and Nalbant (1967), validating Mori's (1927) *S. microoculus*, divided *S. variegatus* into two subspecies, *S. variegatus variegatus* occurring in Japan and *S. variegatus wakiiae* (syn. *S. kobayashii* Mori and *S. koreensis* Mori) occurring in Korea, and *S. microoculus* into two subspecies, *S. microoculus microoculus* distributed in Japan and *S. microoculus kiangsiensis* confined to the lower Yangtze basin and southern China. On the basis of the distributions of these species and subspecies, they postulated that the long-headed *S. microoculus* might have dispersed from southern China through Taiwan to Japan, while the short-headed *S. variegatus* from Korea to Japan.

In all these studies, specimens from Japan are mostly from Lake Biwa or otherwise derived from transplanted Lake Biwa populations in other localities, and indigenous populations in areas other than Lake Biwa have remained un-

examined. In this study I examined populations of *Sarcocheilichthys* from various localities in Japan and Korea, in order to elucidate the taxonomic status and relationships of the Japanese populations.

Materials and methods

Material examined includes a total of 743 specimens of *Sarcocheilichthys* collected from 46 localities in Japan and Korea during the period between 1974 and 1982. In the list of material below, collecting localities are indicated by the locality numbers as designated in Fig. 1. The abbreviations prefixed to the catalogue numbers represent the following institutions: FAKU: Department of Fisheries, Faculty of Agriculture, Kyoto University; OHSKU: Otsu Hydrobiological Station, Kyoto University.

Sarcocheilichthys variegatus variegatus (greyish fluvial form). FAKU 50984, 2 specimens, 66.0~74.6 mm in standard length (SL), locality number 1; OHSKU, 2 uncatalogued specimens, 77.0~79.6 mm SL, loc. 2; FAKU 50746~50750, 50983, 6, 75.6~105.8 mm SL, loc. 3; FAKU 50751, 50770, 51005~51011, 30, 50.0~128.1 mm SL, loc. 21; FAKU 50754~50760, 51015, 8, 28.6~54.2 mm SL, loc. 22; FAKU 50752~50753, 8, 77.7~125.2 mm SL, loc. 24; FAKU 51025, 1, 81.2 mm SL, loc. 25; FAKU 51016, 4, 63.5~89.5 mm SL, loc. 26; FAKU 50761, 51017~51018, 4, 65.9~76.8 mm SL, loc. 27; FAKU 50693~50698, 50745, 93, 18.5~82.2 mm SL, loc. 28; FAKU 50762~50768, 7, 28.0~62.9 mm SL, loc. 29; FAKU 51019, 1, 22.1 mm SL, loc. 30; FAKU 51020, 1, 128.6 mm SL, loc. 31; FAKU 50699~50705, 36, 35.0~89.7 mm SL, loc. 32; FAKU 51021, 1, 114.2 mm SL, loc. 33; FAKU 51022, 1, 130.7 mm SL, loc. 34; FAKU 51023~51024, 2, 58.8~61.1 mm SL, loc. 35; FAKU 50769, 10, 58.5~95.7 mm SL, loc. 36; FAKU 50706~50716, 11, 58.7~106.4 mm SL, loc. 37; FAKU 50742~50744, 3, 59.9~101.2 mm SL, loc. 38; FAKU 50733~50741, 9, 68.3~105.5 mm SL, loc. 39; FAKU 50717~50723, 7, 50.0~86.5 mm SL loc. 40; FAKU 50724~50732, 9, 55.9~94.9 mm SL, loc. 41.

Sarcocheilichthys variegatus microoculus (greyish lacustrine form). FAKU 50797~50798, 33, 35.1~109.0 mm SL, loc. 4; FAKU 50771~50784, 50938~50940, 50985~50990, 110, 36.0~153.8 mm SL, loc. 5; 50785~50786,

13, 81.9~161.5 mm SL, loc. 6; FAKU 50787~50788, 12, 40.5~68.1 mm SL, loc. 7; FAKU 50789, 10, 83.1~159.5 mm SL, loc. 8; FAKU 50919, 24, 65.2~122.7 mm SL, loc. 9; FAKU 50790~50791, 4, 117.6~143.0 mm SL, loc. 10; FAKU 50792~50794, 22, 83.1~150.1 mm SL, loc. 11; FAKU 50795, 5, 58.6~76.2 mm SL, loc. 12; FAKU 50799~50802, 26, 43.4~167.4 mm SL, loc. 13; FAKU 50803~50807, 46, 57.7~162.0 mm SL, loc. 14; FAKU 50808~50809, 12, 62.6~128.3 mm SL, loc. 15; FAKU 50796, 8, 62.0~70.9 mm SL, loc. 16; FAKU 50811, 1, 64.3 mm SL, loc. 17; FAKU 51001~51004, 9, 50.5~96.4 mm SL, loc. 18; FAKU 50810, 1, 72.7 mm SL, loc. 19; FAKU 50815, 3, 68.7~74.9 mm SL, loc. 20; FAKU 50816~50817, 51012~51014, 25, 40.2~123.9 mm SL, loc. 23.

Sarcocheilichthys variegatus wakiyae. FAKU 51027, 5 specimens, 65.0~68.4 mm SL, locality number 42; FAKU 50818, 4, 53.2~98.4 mm SL, loc. 43; FAKU 50821~50822, 7, 73.5~94.7 mm SL, loc. 44; FAKU 50819~50820, 4, 65.9~93.9 mm SL, loc. 45; FAKU 50823~50828, 20, 67.5~124.5 mm SL, loc. 46.

Sarcocheilichthys variegatus subsp. (pale violet-brown form). FAKU 50894~50895, 2 specimens, 90.1~94.2 mm SL, locality number 9.

Sarcocheilichthys biwaensis (yellow-brownish form). FAKU 50883~50884, 3 specimens, 86.7~108.1 mm SL, locality number 4; FAKU 50860~50881, 50991~50993, 50996, 50998~51000, 73, 36.2~141.7 mm SL, loc. 5; FAKU 50890, 50997, 2, 93.8~94.9 mm SL, loc. 6; FAKU 50882, 1, 86.8 mm SL, loc. 8; FAKU 50891~50893, 3, 90.1~98.4 mm SL, loc. 9; FAKU 50885~50889, 50994~50995, 9, 61.1~118.2 mm SL, loc. 13.

Comparative materials.

Sarcocheilichthys nigripinnis nigripinnis. FAKU 50450~50451, 50897, OHSKU, uncatalogued, 16 specimens, 65.8~99.0 mm SL, Yangtze-Kiang, China.

Sarcocheilichthys nigripinnis czerskii. FAKU 50898~50899, 50916, 3 specimens, 69.9~76.6 mm SL, Guem River, Korea; FAKU 50900~50904, 7, 42.3~65.6 mm SL, Mangyeong River, Korea; FAKU 50905~50910, 6, 90.9~124.5 mm SL, Han River, Korea.

Sarcocheilichthys parvus. FAKU 50457~50458, 50917~50918, 4 specimens, 42.7~55.8 mm SL, Canton, China.

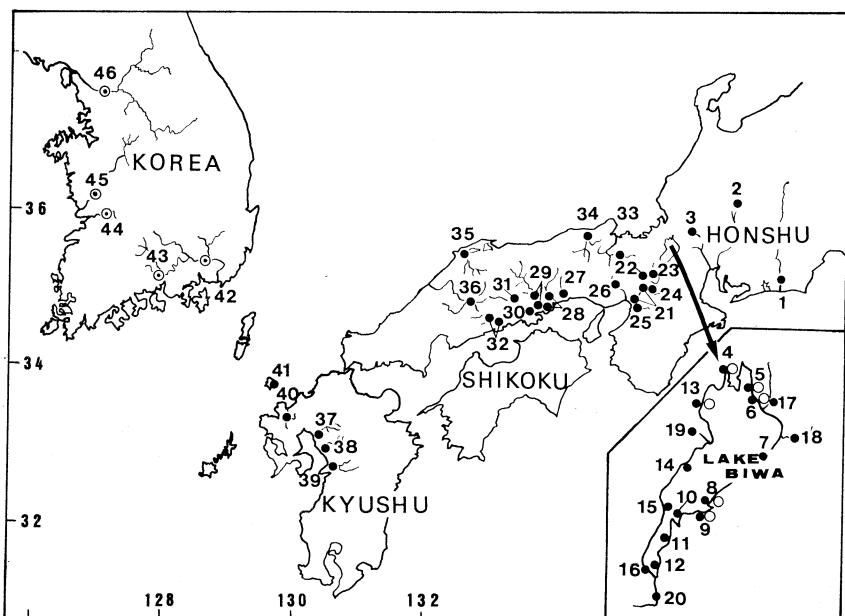


Fig. 1. Collecting sites of *Sarcocheilichthys* in Japan and Korea. ●, greyish forms (*S. variegatus variegatus* and *S. variegatus microoculus*); ○, brownish form (*S. biwaensis*); ◉, *S. variegatus wakiyae*. 1, Tenryu R.; 2, Kiso R.; 3, Ibi R.; 4, Lake Biwa, Ōura; 5, Onoe; 6, Minamihama; 7, Hikone; 8, Dezaike; 9, Chōmeiji; 10, Sabae; 11, Akanoi; 12, Kusatsu; 13, Hamabun; 14, Kitakomatsu; 15, Wani; 16, Ōtsu; 17, Yogo R.; 18, Amano R.; 19, Ado R.; 20, Seta R.; 21, Yodo R.; 22, Katsura R.; 23, Kamo R.; 24, Kizu R.; 25, Yamato R.; 26, Muko R.; 27, Chikusa R.; 28, Yoshii R.; 29, Asahi R.; 30, Ashimori R.; 31, Takahashi R.; 32, Ashida R.; 33, Yura R.; 34, Maruyama R.; 35, Hii R.; 36, Basen R.; 37, Yabe R.; 38, Kikuchi R.; 39, Midori R.; 40, Matsuura R.; 41, Hatahoko R.; 42, Nagdong R.; 43, Nam R.; 44, Mangyeong R.; 45, Guem R.; 46, Han R.

Sarcocheilichthys sinensis. FAKU 50455 ~ 50456, 2 specimens, 81.3 ~ 126.0 mm SL, Yangtze-Kiang, China; OHSKU, 2 uncatalogued specimens, 85.8 ~ 91.2 mm SL, Sungari River, China.

Counts and measurements followed the methods of Matsubara (1955). Individuals of more than 50 mm SL were used for proportional measurements.

Morphological observations

Coloration. In the ground color of the body, specimens examined are clearly separated into greyish individuals and brownish individuals. The greyish individuals have a greyish ground color, darker dorsally and whitish ventrally, and black speckles on the sides. The brownish individuals are colored in yellow-brown all over the body. There are a few individuals corresponding to the pale violet-brown form (FAKU

50894 ~ 50895). Their ventral side is whitish as in the greyish individuals. In this paper they are regarded as a color variants of greyish individuals based on this commonness and other characters such as the marking on the dorsal fin. The relationship of the so-called pale violet-brown form will be discussed in another paper.

Greyish individuals occur in all localities including both Lake Biwa and rivers. Brownish individuals are found only in Lake Biwa at Ōura, Onoe, Minamihama, Dezaike, Chōmeiji, and Hamabun, where they occur together with greyish individuals (Fig. 1).

In all greyish individuals, the dorsal fin has a broad black transverse bar which is interrupted posteriorly (Fig. 2A). In *S. variegatus wakiyae* from Korea the cross bar shows basically a similar pattern, but is a little broader than in greyish individuals (Fig. 2B), except for speci-

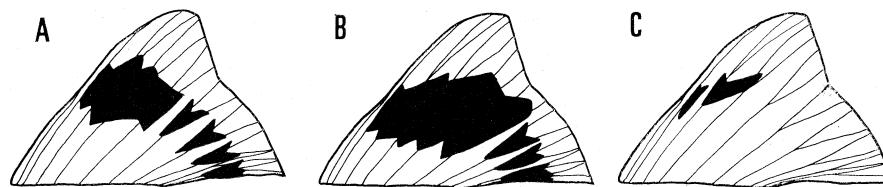


Fig. 2. Marking on the dorsal fin in Japanese and Korean *Sarcocheilichthys*. A: greyish forms (*S. variegatus variegatus* and *S. variegatus microoculus*). B: *S. variegatus wakiyae*. C: brownish form (*S. biwaensis*)

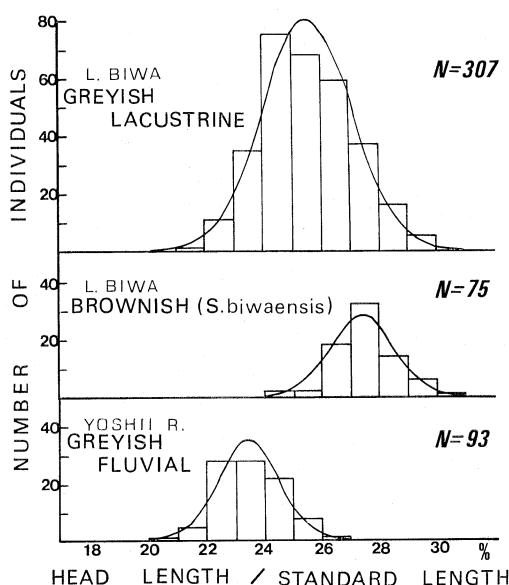


Fig. 3. Relative head length compositions in different populations of *Sarcocheilichthys*. Top: greyish lacustrine form (*S. variegatus microoculus*) in Lake Biwa, middle: brownish form (*S. biwaensis*), bottom: greyish fluvial form (*S. variegatus variegatus*) from Yoshii River.

mens from the Nam River (Fig. 1: locality number 43). In brownish individuals the cross bar at young stages is similar to that of greyish individuals, but the bar reduces in size with growth and finally disappears or becomes small speckles (Fig. 2C).

From the above observations, individuals can be divided into greyish and brownish forms. Subdividing the greyish form into lacustrine and fluvial forms according to habitat, morphological comparisons are hereafter made between the greyish lacustrine, greyish fluvial, and brownish lacustrine forms. Hereafter they are abbrevi-

ated as the lacustrine, fluvial and brownish forms, respectively.

Head length. In the ratio of the head length to the standard length, all these three forms show unimodal normal-distributions (lacustrine form: $X=7.088 < \chi^2_{0.05}$; fluvial form: $X=3.577 < \chi^2_{4;0.05}$; brownish form: $X=6.403 < \chi^2_{4;0.05}$) (Fig. 3). The head tends to be longer in the lacustrine and brownish forms (range of means at different localities: 24.0~27.6% and 27.0~27.8%, respectively), shorter in the fluvial form (23.2~26.7%) (Fig. 4). The Korean *S. variegatus wakiyae* shows small ratios (22.6~23.5%). In the fluvial form the ratio is exceptionally great at the Seta and Kamo Rivers (Fig. 1: locality numbers 20 and 23), which originate from Lake Biwa and empty into Osaka Bay.

Depth of caudal peduncle. The depth of the caudal peduncle in relation to the standard length tends to be lower in the lacustrine and brownish forms (range of means: 10.2~11.2% and 10.6~11.3%, respectively) and higher in the fluvial form (11.0~12.9%) (Fig. 5). In *S. variegatus wakiyae* the caudal peduncle is high (12.5~13.0%). The fluvial form shows a gentle geocline, the relative depth being high in the west and low in the east, although it discontinues between the Muko River (Fig. 1: locality number 26) and the Chikusa River (locality number 27).

Length of caudal peduncle. The length of the caudal peduncle in relation to the standard length tends to be shorter in the brownish form (range of means: 19.2~19.8%), longer in the fluvial form (21.2~23.2%), and intermediate in the lacustrine form (19.2~22.1%) (Fig. 6). In *S. variegatus wakiyae* the caudal peduncle is long on the whole (21.3~23.6%), but there

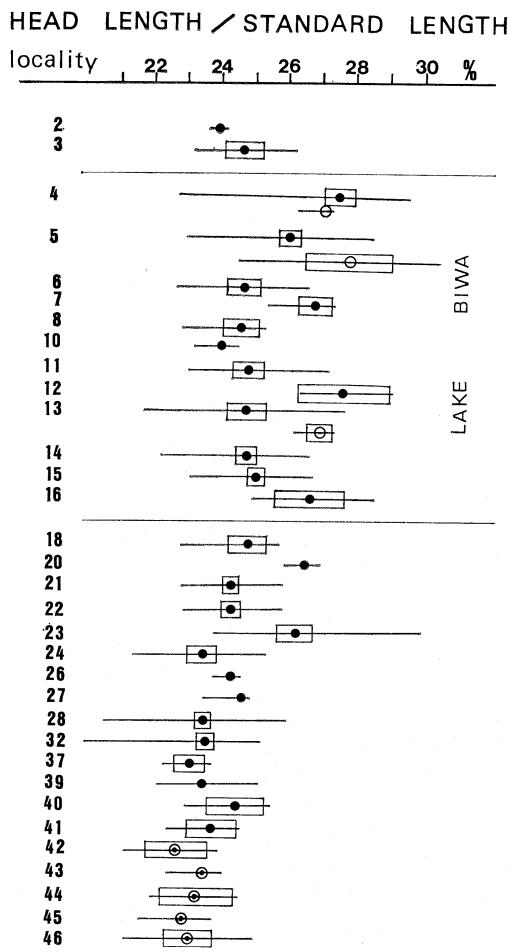


Fig. 4. Geographic variation in the ratio of head length to standard length (%) in Japanese and Korean *Sarcocheilichthys*. ●, greyish forms (*S. variegatus variegatus* and *S. variegatus microculus*), ○, brownish form (*S. biwaensis*), ⊙, *S. variegatus wakiyae*. The diagram indicates the mean (center point), 95% confidence interval (rectangle) and range (horizontal line). Localities are indicated by the locality numbers given in Fig. 1.

is a more or less distinct gap between specimens from the Nagdong and Nam Rivers (19.2~22.1%) and those from the other localities in Korea (23.1~23.6%).

Eye diameter. In the description of *S. microculus* for long-headed individuals in Lake Biwa, Mori (1927) listed "small eyes" as one of its

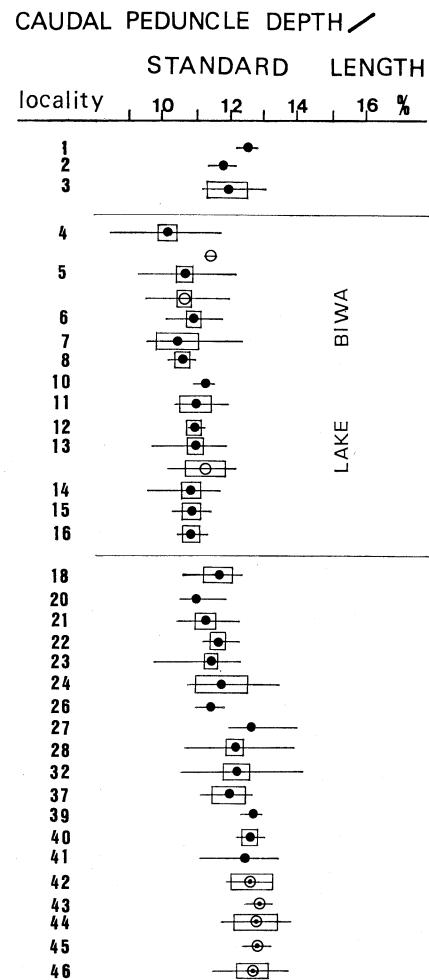


Fig. 5. Geographic variation in the ratio of depth of caudal peduncle to standard length (%) in Japanese and Korean *Sarcocheilichthys*. For explanation of diagram, see legend for Fig. 4.

specific characters. In order to examine the validity of the eye diameter as a diagnostic character, 50 individuals each of the lacustrine and brownish forms of Lake Biwa were sampled at random for plotting. In the lacustrine form a positive correlation ($r=0.965$, $P<0.01$) is recognized between the eye diameter and head length (Fig. 7). The brownish form shows a similar pattern ($r=0.969$, $P<0.01$), but their eyes are smaller than the lacustrine form, particularly at early stages (Fig. 7). In both cases it is difficult to choose a valid population

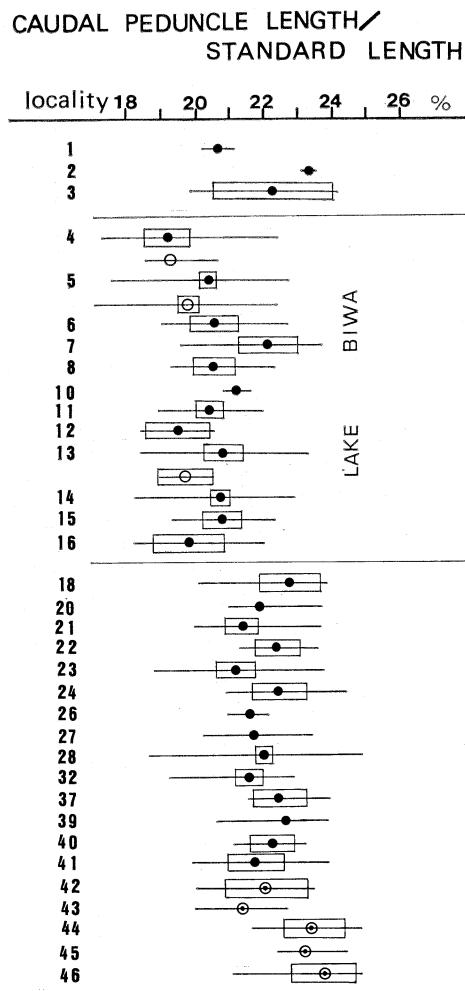


Fig. 6. Geographic variation in the ratio of caudal peduncle length to standard length (%) in Japanese and Korean *Sarcocheilichthys*. For explanation of diagram, see legend for Fig. 4.

having specifically small eyes.

Horny sheath. Another diagnostic character of *S. microoculus* employed by Mori (1927) is the tip of the lower jaw which is "fleshy or only a little horny". After detailed examination of this character, I came to have a different interpretation from that of Mori (1927).

An underdeveloped horny sheath is common to all specimens from Honshu, regardless of variations in the head length and coloration (Fig. 8). On the other hand, the horny sheath of the Korean *S. variegatus wakiiae* is so well

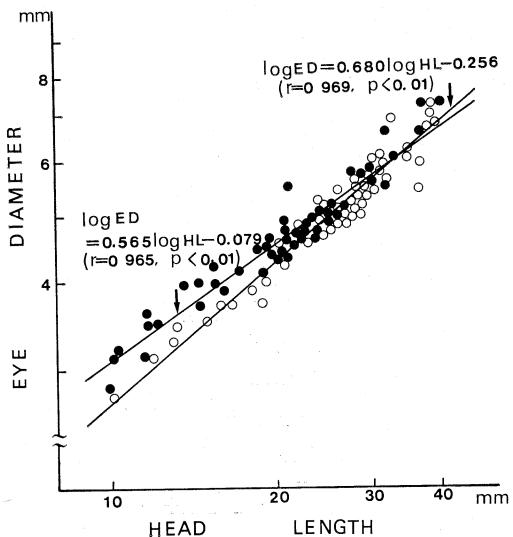


Fig. 7. Relationship between eye diameter and head length in two forms of *Sarcocheilichthys* in Lake Biwa. ●, greyish lacustrine form (*S. variegatus microoculus*); ○, brownish form (*S. biwaensis*).

developed that it is visible to the naked eye. The extent of this development in the specimens from Kyushu is intermediate between that of Honshu specimens and *S. variegatus wakiiae*.

These observations suggest that the development of the horny sheath is subject to geographic variation, and hence is considered to be a subspecific, rather than specific, character.

Depression on snout. Bănărescu and Nalbant (1967, 1973) listed the presence of a groove or deep depression on the top of the snout as a peculiar character of *S. microoculus microoculus*. According to my observations, the depression is present in 52.9% of the lacustrine form, 11.6% of the fluvial form of the Yoshii River (Fig. 1: locality number 28), 18.8% of *S. variegatus wakiiae*, and 90.6% of the brownish form. Presence of the groove appears to be related to the prolongation of the head, because specimens with a head length of more than 25~27% of SL usually have this depression.

Configuration of bone elements in the snout region was compared to examine the mechanism of the formation of the groove (Fig. 9). In specimens with short heads, space is narrow between the ethmoid region and rostral bone which functions in the opening and shutting of

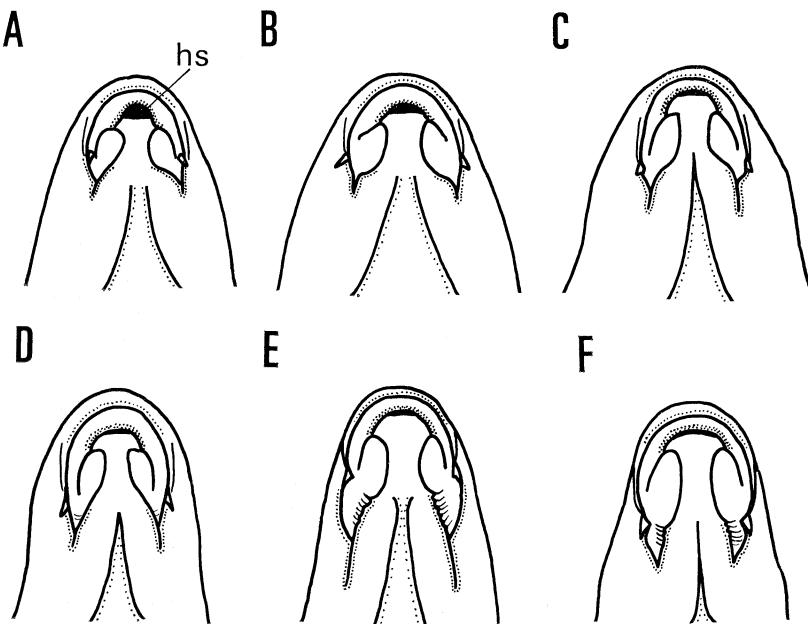


Fig. 8. Ventral views of the mouth of several forms of Japanese and Korean *Sarcocheilichthys*. A: *S. variegatus wakiyae*. B: Greyish fluvial form (*S. variegatus variegatus*) from Yabe River, C~E: Greyish lacustrine form (*S. variegatus microculus*) from Lake Biwa (C: short-headed; D: Medium-size-headed; E: long-headed). F: brownish form (*S. biwaensis*). hs, horny sheath on mandibular symphysis.

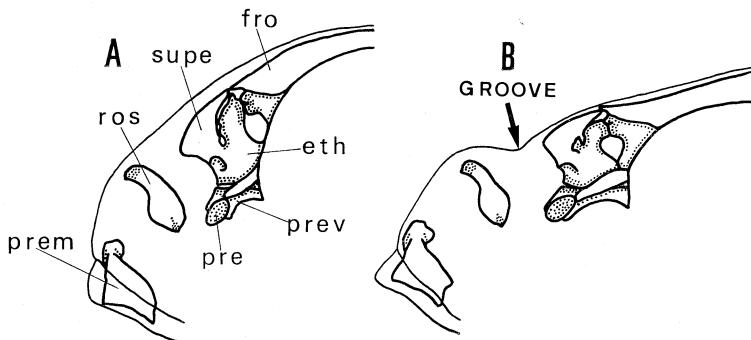


Fig. 9. Configuration of bone elements of the upper jaw and snout in Japanese *Sarcocheilichthys*. A: short-headed individual, B: long-headed individual. eth, ethmoid; fro, frontal; pre, preethmoid; prem, premaxillary; prev, prevomer; ros, rostral.

the upper jaw. In long heads, it is so wide that the snout dorsum becomes concave and thus produces a groove. So, this character appears to be subject to the prolongation of the head, and caused by the growth-rate difference between the head and the neurocranium.

Brain morphology. Since there would be some differences in the brain morphology as-

sociated with the variation in the head length, the shape of the brain was compared between long-, medium-size-, and short-headed individuals of the lacustrine form, fluvial form, brownish form and *S. variegatus wakiyae*.

No significant difference is observed in brain shape except for the length of the olfactory tract which separates the olfactry bulb from the

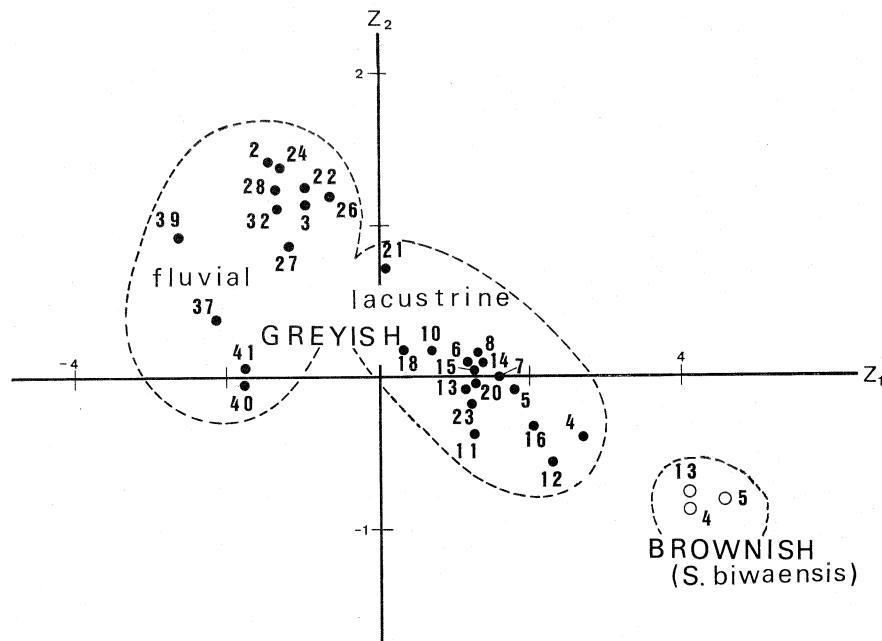


Fig. 10. Populations of the genus *Sarcocheilichthys* in Japan, scattered according to the score given by the first (Z_1) and second (Z_2) principal components. ●, greyish forms (*S. variegatus variegatus* and *S. variegatus microoculus*); ○, brownish form (*S. biwaensis*).

olfactory lobe. The length of the olfactory tract of the long-headed lacustrine form and brownish form was the longest, that of the short-headed lacustrine form, fluvial form and *S. variegatus wakiyae* the shortest, and that of the medium-size-headed lacustrine form intermediate.

Yonezawa (1958) reported that the rhomboid fossa of the medulla oblongata was dorsally visible in short-headed individuals of the lacustrine form, but not in the brownish form. However, no difference in the development of both the facial and vagal lobes was observed between any forms in this study.

Pattern analysis

Based on the above morphological observations, head length, caudal peduncle depth, caudal peduncle length, horny sheath, dorsal cross bar, and olfactory tract can be considered to satisfy the criterion for use in the taxonomy. For evaluating morphological similarities, principal component analysis was applied. Before calculation, qualitative characters were quantified by the points which reflected the polarity of morphocline in accordance with Maslin (1952).

The following three grades, 0 for primitive, 1 for neutral, and 2 for specialized, were employed: Coloration: 0, densely speckled; 1, variable; 2, ventral side colored. Horny sheath: 0, well developed; 1, moderately developed; 2, thin. Dorsal cross bar: 0, broad; 1, narrow; 2, reduced to a few small speckles or none. Olfactory tract length: 0, short; 1, variable; 2, long. These characters were prepared for the calculation, together with each mean of proportional measurements.

From principal component analysis, four principal components, $Z_1 \sim Z_4$, which inclusively covered 98% of the total variance, were obtained. The component score of each locality was calculated for $Z_1 \sim Z_4$. Using the first two component scores, Z_1 and Z_2 , relationships among geographical populations of Japanese forms were displayed in a two-dimensional space (Fig. 10).

With regard to the two principal component axes (Z_1 and Z_2), three significant clusters are segregated, which correspond the lacustrine, fluvial, and brownish forms.

Taxonomic discussion

Morphologically, the brownish form is completely separated from the greyish forms, and the greyish lacustrine and the greyish fluvial forms are more or less clearly distinctive (Fig. 10).

The fluvial form agrees with the original description of *Sarcocheilichthys variegatus* (Temminck and Schlegel, 1846, as *Leuciscus variegatus*). It is characterized by having dense speckles on the body sides, a short head, a well-developed caudal peduncle and a bluntly forked caudal fin. Among the lacustrine form, long-headed individuals agree with the original description of *S. microculus* (Mori, 1927), which is characterized by having a long head, small eyes and an underdeveloped horny sheath at the anterior margin of the lower jaw. The Chinese *S. microculus kiangsiensis* differs from Japanese long-headed individuals in having no cross bar on the dorsal fin and 1 or 2 more branched soft dorsal fin-rays (Nichols, 1930, 1943; Bănărescu and Nalbant, 1967, 1973). From these differences, it can be concluded that *S. microculus microculus* is specifically different from *S. microculus kiangsiensis*. The Korean *S. variegatus wakiyae* shares with Japanese greyish forms the dorsal cross bar, one-rowed pharyngeal teeth, and the absence of a longitudinal band on the upper and lower margin of the caudal fin, but differs from the Japanese forms in having a well-developed horny sheath, more dense speckles and a broader dorsal cross bar.

On the basis of the above observations, I conclude that the greyish fluvial form, the greyish lacustrine form and *S. variegatus wakiyae* represent distinct subspecies within *S. variegatus*. Because the characters of the greyish fluvial and lacustrine forms agree with the original descriptions of *S. variegatus* and *S. microculus*, respectively, I classify the greyish fluvial form as *S. variegatus variegatus* (Temminck et Schlegel) and the greyish lacustrine form as *S. variegatus microculus* Mori. Their distributions are given in the key to the species and subspecies of Japanese *Sarcocheilichthys*.

The brownish form, which has been treated by several authors as one of color variants, is described below as a new species.

Sarcocheilichthys biwaensis sp. nov.

(Japanese name: Abura-higai)

(Figs. 2C, 8F, 10, 11)

Sarcocheilichthys variegatus (Temminck et Schlegel): Araki, 1935: 3; Bureau of Fisheries (Japan), 1938: 2, pls. I, II; Uchida, 1939: 240; Aoyagi, 1957: 115; Yonezawa, 1958: 20, pl. I, II; Okada, 1959~1960: pl. XXVI 4; Nakamura, 1963: 118, fig. 44B a~c, 1969: 154, pl. 111B, C; Miyadi et al., 1976: 172; all in part, designated as greasy type of *S. variegatus* or as abura-higai in Japanese.

Holotype. FAKU 50831, male, 135.3 mm SL, April 3, 1976, Lake Biwa at Onoe, Shiga Pref., Japan, by a local set-net 'eri'.

Paratypes. FAKU 50832, female, 135.4 mm SL, April 3, 1976; FAKU 50871~50874, 1 male and 3 females, 103.6~141.7 mm SL, May 23, 1979; all collected at the type locality by the same gear.

Diagnosis. Body yellowish brown; ventral side colored almost as dark as dorsal side; no stripes on sides. Dorsal fin with or without one or two small black speckles. Head long, more than 24.5% of SL. Barbels one pair, their tip blunt. Eyes small, less than 5.3% of SL. Branchiostegal rays forming distinct striations readily visible from outside. Pharyngeal teeth one-rowed. Distal one-third of principal spiny ray of dorsal fin flexible.

Description. Based on the holotype and five paratypes; data for the paratypes, when different, are given in parentheses.

D. iii, 7; A. ii, 6; P_1 14 (15); P_2 8; C. 19; Lateral-line scales 43 (42~43); vertebrae 40 (39~41) including 4 Weberian apparatus elements; branchiostegal rays 3; pharyngeal teeth 5~5; gillrakers 5 (5~7); dorsal proximal pterygiophores 8; anal proximal pterygiophores 7.

Proportional measurements are shown in Table 1. Body elongate and moderately compressed. Head long. Snout long, dorsal profile convex with a depression posteriorly, tip bluntly rounded. Nape abruptly rising backward. Eyes small and high. Mouth small, subinferior and protractile; lips fleshy; anterior margin of lower jaw covered with a poorly developed horny sheath. Barbels one pair, their tips blunt. Chin angular ventrally, with an inconspicuous small lump. Branchiostegal rays forming dis-

tinct striations readily visible from outside. Distal one-third of principal spiny ray of dorsal fin flexible.

Lateral line complete. Infraorbital canal of cephalic lateralis connected to supraorbital, preoperculo-mandibular, and temporal canals; posttemporal canal directly connected to the counterpart on the middle line of both parietals, not running through supraoccipital. Pores (including both ends of each canal) 8 on supraorbital, 15 on infraorbital, 13 on preoperculo-mandibular, and 7 (7 or 9) on posttemporal.

Color in life: Body including ventral surface yellowish brown with a dull iridescence; no dark speckles on sides; a broad dark-brown longitudinal band running along the posterior half of lateral line; a black crescent mark behind opercle. All fins pale yellow; dorsal fin with or without one or two small black speckles (usually inconspicuous or disappearing in adults).

Name. The name *biwaensis* refers to Lake

Biwa, to which it is endemic.

Biology. The spawning season extends from late April to early June, reaching a peak between mid May and early June. Eggs are pinkish, in contrast to yellow as in *S. variegatus*. Sex ratio (male: female) is 1:2 at Ōura, 29:47 at Onoe, 5:4 at Hamabun. This species is endemic to Lake Biwa, and its habitats in the lake are confined to basalt rocky or pebbly shores. It never moves to the affluent or effluent rivers of Lake Biwa in any season, unlike *S. variegatus*. Food consists of freshwater invertebrates, chiefly larvae of the Trichoptera and Chironomidae and small gastropods.

Comparison. Miyadi et al. (1976) suggest a kinship between this species and the Korean *S. kobayashii* Mori (type locality: Nagdong River; synonymized by Uchida (1939) with *S. wakiyae*). Comparison of *S. biwaensis* with specimens from the Nagdong River referable to *S. kobayashii* (FAKU 51027) shows that *S. biwaensis* differs

Table 1. Counts and measurements expressed as percentage of standard length in *Sarcocheilichthys biwaensis* sp. nov. Vertebral counts include 4 Weberian apparatus elements.

Catalogue number	Holotype		Paratype		
	FAKU 50831	FAKU 50832	FAKU 50871	FAKU 50872	FAKU 50873
Sex	♂	♀	♀	♀	♀
Standard length (mm)	135.3	135.4	141.7	120.1	114.4
Total length (mm)	161.5	159.0	161.9	143.5	136.6
Head length (%)	27.42	24.45	27.31	26.56	26.57
Snout length	10.94	9.82	10.30	9.91	9.79
Interorbital width	7.83	7.75	7.90	7.83	7.78
Eye diameter	4.43	5.10	4.80	4.66	5.24
Body depth	23.12	23.04	24.98	25.06	24.83
Body width	16.63	14.55	15.38	15.82	15.47
Depth of caudal peduncle	11.09	9.45	9.95	10.24	10.23
Length of caudal peduncle	19.14	17.06	19.91	20.98	20.72
Predorsal length	49.89	49.63	49.75	41.87	50.70
Preanal length	75.61	76.00	77.63	74.44	76.05
Length of longest dorsal soft ray	19.88	18.39	18.07	16.29	19.32
Length of longest anal soft ray	15.08	14.18	13.55	12.27	15.12
Ovipositor length	—	4.73	13.34	14.24	11.87
Dorsal fin rays	iii, 7				
Anal fin rays	ii, 6				
Pectoral fin rays	14	15	15	15	15
Pelvic fin rays	8	8	8	8	8
Principal caudal fin rays	19	19	19	19	19
Lateral-line scales	43	43	43	43	42
Vertebrae	40	41	41	41	40

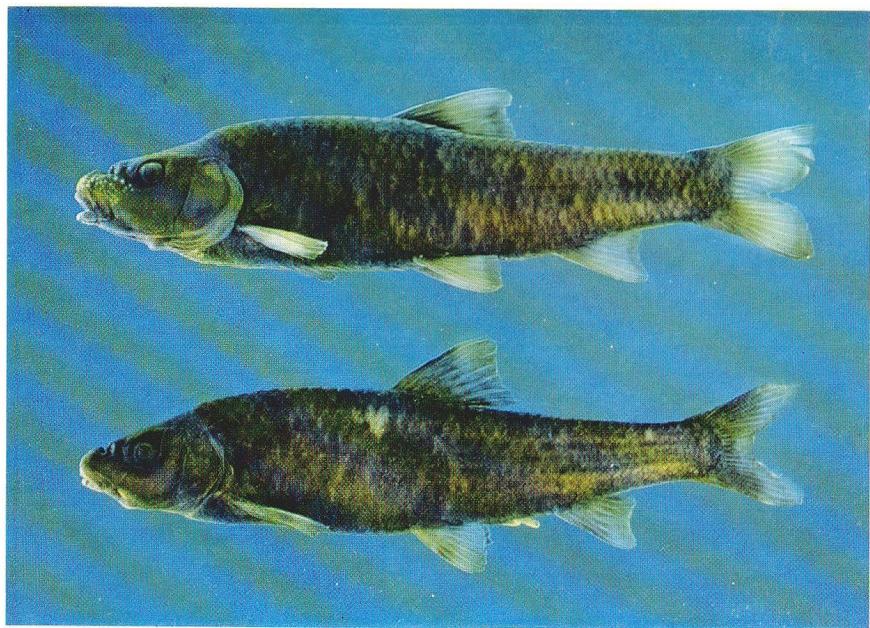


Fig. 11. *Sarcocheilichthys biwaensis* sp. nov. Top: holotype, FAKU 50831, male, 135.3 mm SL. Bottom: a paratype, FAKU 50832, female, 135.4 mm SL.

from *S. kobayashii* in having a long head (range 21.7~24.0%, mean 22.9% of SL in *S. kobayashii*), a brownish ventral side of the body (whitish in *S. kobayashii*), and 1~2 more lateral-line scales (41~42, mean 41.2 in *S. kobayashii*). From other continental congeners except for *S. sinensis*, this species is distinct by the dark-colored ventral side of the body. From *S. sinensis* this species differs in having one-rowed pharyngeal teeth (two-rowed in *S. sinensis* (Chu, 1935)) and a more flexible principal spiny ray of the dorsal fin, and in the absence of black vertical stripes on the sides of the body. From the other Japanese forms of *Sarcocheilichthys*, it is readily distinguishable by the key given below.

Key to the species and subspecies of Japanese *Sarcocheilichthys*

A₁ Ventral side of body yellowish brown; barbels present, their tip blunt; branchio-stegal rays forming several distinct stria-tions; 0~2 small black speckles on dorsal fin. Indigenous to Lake Biwa except for southern shores
 *Sarcocheilichthys biwaensis* sp. nov.
 (Abura-higai)

A₂ Ventral side of body pale; barbels present

or absent, if present its tip conical; branchiostegal rays not forming striated folds; a broad black cross bar on dorsal fin.
.... *Sarcocheilichthys variegatus* (Higai)

B₁ Depth of caudal peduncle more than 49% of head length; posterior margin of caudal fin bluntly forked. Indigenous to rivers of southwest Japan except Shikoku.....
 *Sarcocheilichthys variegatus variegatus*
 (New Japanese name: Kawa-higai)

B₂ Depth of caudal peduncle less than 49% of head length; posterior margin of caudal fin sharply forked. Indigenous to Lake Biwa, Seta River, and Kamo River. Transplanted to Tōhoku, Kantō, Hokuriku, Lake Suwa, and Shikoku

.... *Sarcocheilichthys variegatus microoculus*
 (New Japanese name: Biwa-higai)

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日本産ヒガイ属魚類の分類とアラヒガイの新種記載 細谷和海

種々の変異型が知られている日本産ヒガイ属魚類について、形態質の比較研究を行った。有効な分類形質を主成分分析した結果、河川に生息する個体群、琵琶湖産正常色型、アラヒガイの3つのグループに整理できた。河川産の個体は正常色・短頭型で *S. variegatus variegatus* (カワヒガイ, 新称) に、琵琶湖産正常色型はやや長頭で *S. variegatus microoculus* (ビワヒガイ, 新称) に分類した。ツラナガ・トウマル・ヒガイはどの形質においても連続し、独立した個体群として区別できなかった。アラヒガイは体色が濃黄褐色を呈し、長頭で、背鰭黒色横帯が退化的パターンを示すなど最も特殊化している。これらの特徴に基づきアラヒガイを新種 *S. biwaensis* として記載した。

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